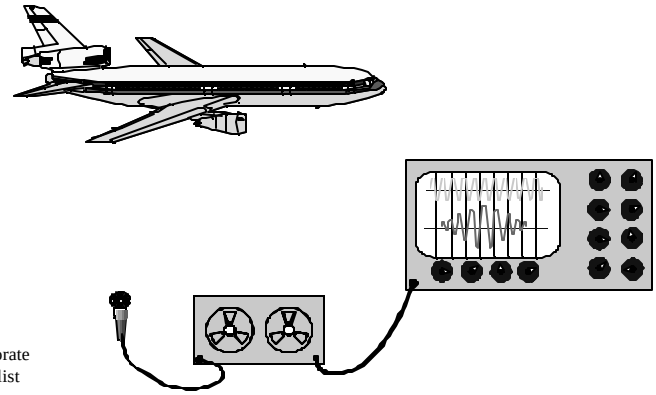
Aircraft Acoustics



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Background

- **Regulations and Policy**
  - Responsible Organizations
  - ACOs
  - Requirements for compliance
  - Rule Changes
  - Increased stringency
  - Hushkits
  - Differential Global Positioning Systems (DGPS)

Background

- **Part 36 Reference Conditions**
  - Transport
  - General Aviation
  - Helicopters
- **Sources**
  - Engine
  - Airframe
- **Noise Reduction Methods**

Background

- **Equivalent Procedures**
- **Correlating Parameters**
- **Acoustic Change**
  - Potential acoustic changes
  - Methods to evaluate
  - Exclusions
- **Foreign Authorities**

Regulations and Policy

- **Office of Environment and Energy (AEE)**
  - Responsible for all regulatory and policy actions
- **Directorates**
  - Noise Certification Specialists
    - Transport Airplane Directorate
      - Directorate oversight of large and turbojet powered airplane noise certification
    - Small Airplane Directorate
      - Directorate oversight of small and commuter category airplane noise certification
    - Rotorcraft Directorate
      - Directorate oversight of rotorcraft noise certification

Regulations and Policy

- **Aircraft Certification Offices**
  - Noise Focal Points
    - Primary contact for the dissemination of policy changes
  - Responsible for making findings of compliance to 14 CFR part 36 requirements
  - Coordinates closely with appropriate NCS on all equivalencies, hushkits, and any unusual compliance proposals.

Requirements for Compliance

- **14 CFR part 21**
  - For new Type Certificates § 21.17, § 21.25, § 21.29
  - For changes to Type Certificates § 21.93(b), § 21.101
  - For Supplemental Type Certificates § 21.115
- **14 CFR part 36**
  - Large airplanes (>12,500 lbs. MTOW), and for subsonic turbojet powered airplanes § 36.2(a)(1)
  - Propeller driven commuter category and small airplanes § 36.2(a)(2)
  - Helicopters § 36.2(a)(4)

Requirements for Compliance

- **Prior to issuance of a new Type Certificate**
  - Current Amendment to Part 36 on date of issuance must be complied with
  - Noise Control Act Finding
  - New noise rules (e.g. tiltrotor)
  - If noise rules are not applicable an Environmental Assessment (EA) is required
    - Airships
    - Large Propeller Driven Airplanes that do not have standard airworthiness certificates

Requirements for Compliance

- **Prior to issuance of a Supplemental Type Certificate**
  - All applicable noise requirements are met through
    - Direct compliance showing
    - If additional modifications are required (e.g., hushkits for a gross weight increase) they are specifically listed in the Limitations and Conditions section of the STC
  - Compliance to current amendment level of Part 36 may be required even though aircraft is very old

Categorical Exclusions

- **Aircraft Specifically Excluded from compliance**
  - Commuter category and small airplanes
    - Designed for agricultural aircraft operations (as defined in § 137.3)
    - For dispersing firefighting materials
  - Helicopters
    - Designed for agricultural aircraft operations (as defined in § 137.3)
    - For dispensing firefighting materials
    - For carrying external loads (as defined in § 133.1(b))

Regulations and Policy

- **Rule changes**
  - Initiated by AEE
  - Coordinated with JAA for harmonization
  - Turbojet powered and large airplanes
    - Harmonization NPRM issued July 11, 2000, FR Vol. 65, No. 133
    - AC 36-4C to include changes
  - Small airplanes
    - Rule harmonized October 13, 1999
  - Helicopters
    - Harmonization NPRM to be issued this year

Regulations and Policy

- **Amendment 22 Changes to 14 CFR part 36 Appendix G**
  - Federal Register Volume 64, No. 197 dated Wednesday October 13, 1999
  - Effective December 13, 1999
  - Changes harmonize it with ICAO Annex 16 Chapter 10 and JAR 36

Regulations and Policy

		Was	Is
Equipment	Microphone	4 feet above ground	Inverted 12.7 mm mounted 7 mm above white painted metal plate
Corrections	Temperature	77°F/70% Rh	59°F/70% Rh
	Absorption	Delta(M) = (α - 0.7)H_T/1000	Delta(M) = ($H_T\alpha$ - 0.7H_R) /1000

Regulations and Policy

		Was	Is
Corrections	Helical Tip Mach Number	Must make corrections for off reference Mach number for 1) Variable pitch propellers, and 2) fixed pitch propellers if power is not within 5% of reference	Added: No corrections are required if the helical tip Mach number variation from reference is: 1) Within 0.014 and reference tip Mach is at or below 0.70

Cont. ⇨

Regulations and Policy

		Was	Is
Corrections	Helical Tip Mach Number	Must make corrections for off reference Mach number for 1) Variable pitch propellers, and 2) fixed pitch propellers if power is not within 5% of reference	2) Within 0.007 and reference tip Mach is above 0.70 and at or below 0.80 3) Within 0.005 and reference tip Mach is above 0.80. For mechanical tachometers, if the tip Mach is within 0.008

Cont. ⇨

Regulations and Policy

		Was	Is
Corrections	Power	Delta (3) = 17 log (P_R/P_T)	Delta (3) = K_3 log (P_R/P_T) K_3 may be determined from approved data from the test airplane

Cont. ⇨

Regulations and Policy

	Was	Is
Limits	73 dBA up to 1,320 lbs. and 85 dBA for 3,300 lbs. and above varying 1 dB/165 lbs. between 1,320 and 3,300 lbs.	76 dBA up to 1,320 lbs. varying 9.83 dB per doubling of weight over 1,320 lbs. up to 88 dBA maximum (approximately 3,080 lbs.)

Regulations and Policy

- **Increased Stringency**
  - Turbojet Powered and Large Airplanes
    - Stage 4 proposals in discussion at working group level
  - Small Airplanes
    - No increased stringency
    - Harmonization with JAR 36 and ICAO Annex 16 Volume I, Chapter 10
  - Helicopters
    - In discussion at the working group level

Regulations and Policy

- **Hushkits**
  - Modifications to existing design aircraft and engines to make them meet Stage 3 requirements
  - Highly competitive market
  - Politically sensitive
  - Special policy
    - FAA Memo issued August 15, 1996 requires all hushkit programs to be closely coordinated with the Transport Noise Certification Specialist prior to approval of STC

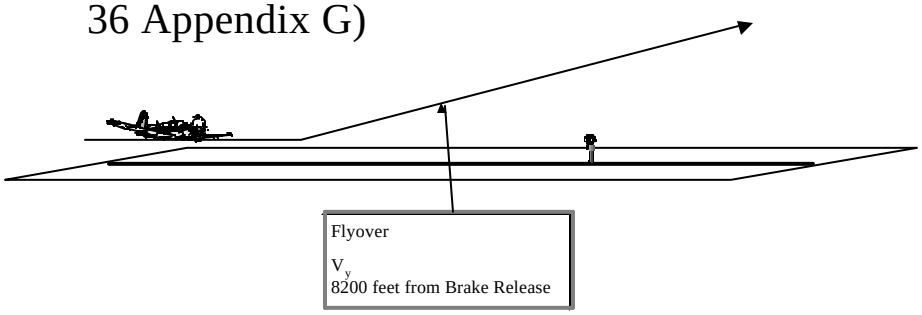
Regulations and Policy

- **Differential Global Positioning Systems**
  - Used for aircraft Time Space Position Information (TSPI)
  - Satellite time code versus IRIG
  - Approval of System
    - Submittal to FAA
    - Reviewed by Volpe
    - Results of review acted upon by FAA

    (Reference Document DTS-75-FA753-LR3)
  - Use of recently unsecured non-dithered GPS is not approved

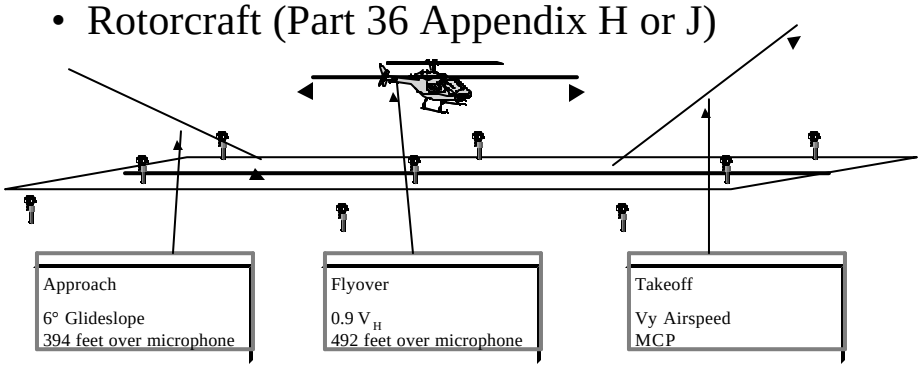
Part 36 Reference Conditions

- Small and commuter category airplanes (Part 36 Appendix G)



Part 36 Reference Conditions

- Rotorcraft (Part 36 Appendix H or J)

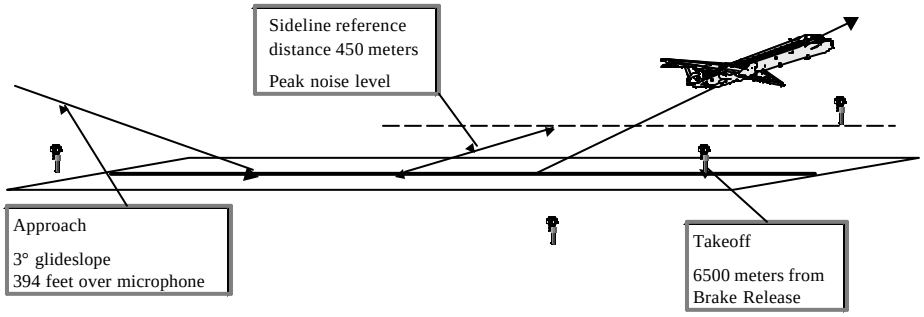


The above profiles apply for the Appendix H testing.

Appendix J uses only the flyover and a single microphone.

Part 36 Reference Conditions

- Large and turbojet powered airplanes (Part 36 Appendix C)



Part 36 Reference Conditions

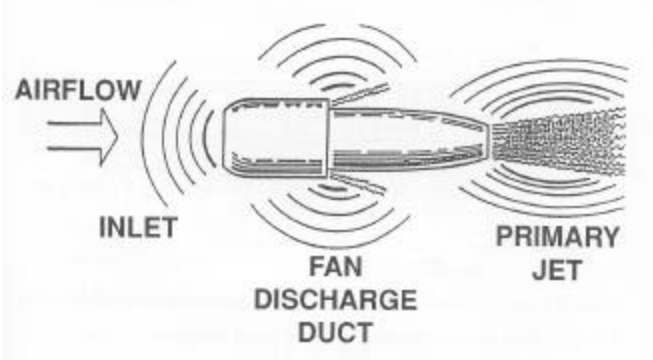
- Testing Conditions
  - Relative humidity (20-95%)
  - Temperature (36-95°F)
  - Absorption
    - 14 dB/100 m (16 dB/100 m for approach)
  - Winds
    - Average (12 kts. Max., 7 kts. Max. crosswind)
    - Gusts (15 kts. Max., 10 kts. Max. crosswind)
  - Airspeed
    - ±3 kts. (3%) during 10 dB down points
    - Within 5 kts. of target

Part 36 Reference Conditions

- Reference atmospheric conditions
  - Zero wind
  - Temperture 77° F
  - Relative humidity 70%
  - Sea level pressure (2116 psf)
- Calculated reference profiles must use reference atmospheric conditions

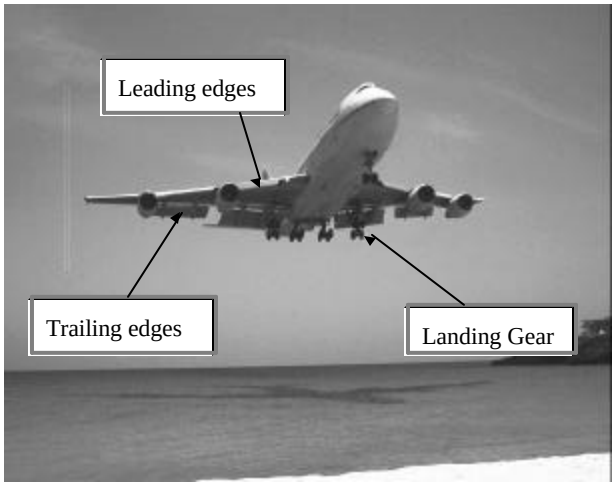
Sources

- Engine



Sources

- Airframe

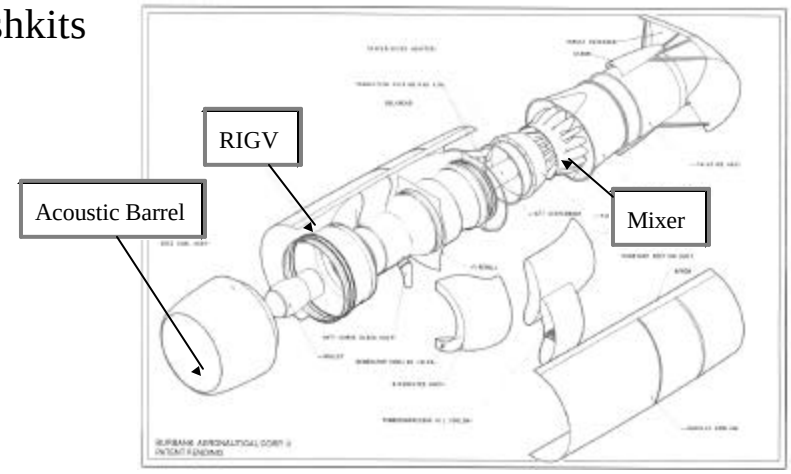


Noise Reduction Methods

- Limitations
  - Maximum gross weight
    - For transport aircraft a gross weight reduction may result in an increase in sideline.
  - Flap restrictions
    - Must be within the limits of certified performance airworthiness
  - Engine derates
- Performance improvements
  - Wing root cuffs
  - Re-rigged slats/flaps

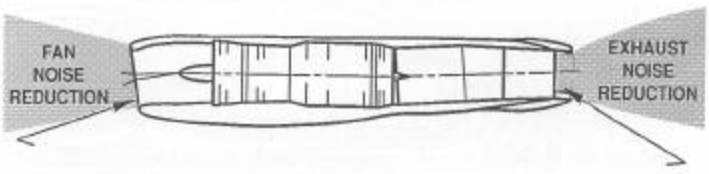
Noise Reduction Methods

- Hushkits



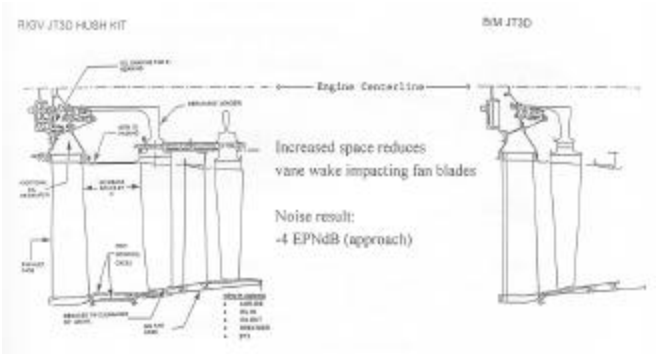
Noise Reduction Methods

- Hushkits
  - Goal is to reduce the primary noise sources of low bypass ratio turbojet engines



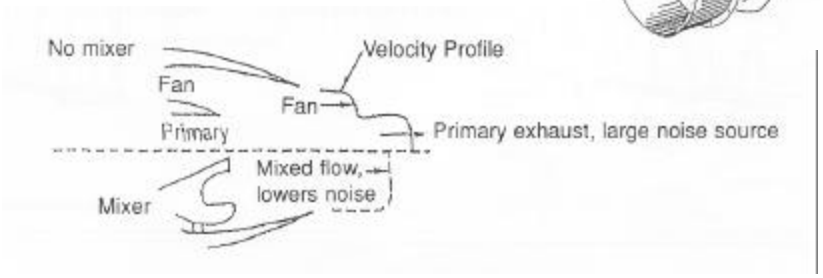
Noise Reduction Methods

- Hushkits
  - RIGV (Respaced Inlet Guide Vanes)



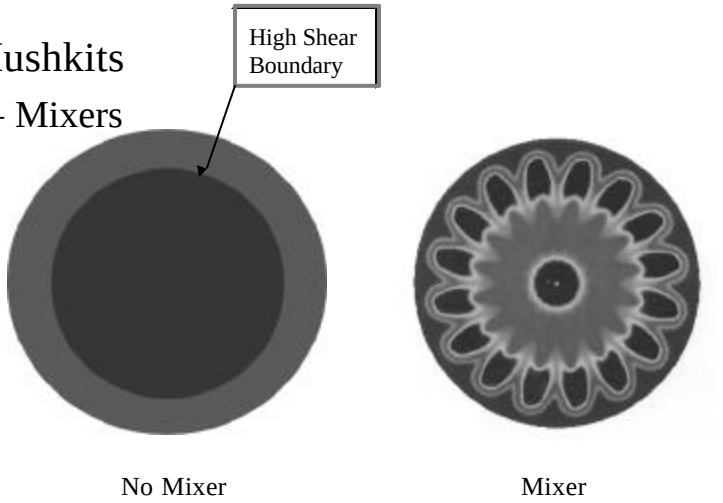
Noise Reduction Methods

- Hushkits
  - Mixers



Noise Reduction Methods

- Hushkits
  - Mixers



Noise Reduction Methods

- Re-Engining
  - Replacement of low bypass ratio turbojet engines with more efficient later design high bypass ratio engines
    - Dee Howard 727
    - Rohr/Valsan 727
    - Boeing (Douglas) DC-8-70 series

Equivalent Procedures

- What are they?
- Why are they needed?
- Who has authority to approve them?
- What are currently in use?

Equivalent Procedures

- What are they?
  - Approved methods or techniques that do not specifically follow the testing requirements of 14 CFR part 36
  - Approved based on achieving the same results if the actual requirements were specifically followed

Equivalent Procedures

- Why are they needed?
  - Some of the specific requirements for testing under 14 CFR part 36 cannot be conducted (e.g., takeoff)
  - Reduce costs to applicants (e.g., noise, power, distance database, family plan)

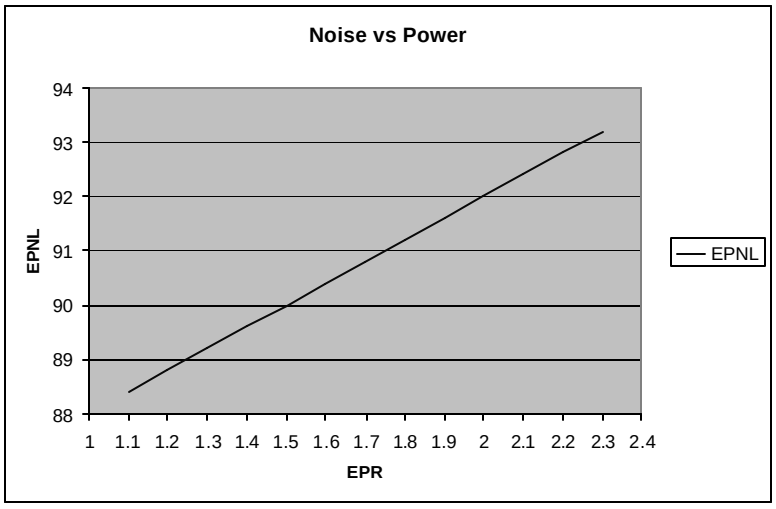
Equivalent Procedures

- Who approves them?
  - AEE (Office of Environment and Energy) are the only ones who can approve an equivalent procedure
    - Authority to approve some types of equivalencies has been delegated to the cognizant Noise Certification Specialist
    - Some well exercised and accepted equivalencies may be used without going through AEE
  - Requires identification **early** in the program to provide time to get approval
  - Reference FAA memo dated January 13, 1995

Equivalent Procedures

- What are currently in use?
  - Flight intercept method
  - Noise/Power/Distance database
  - Family plans
  - Engine equivalencies
  - Constant tip mach for rotorcraft

Correlating Parameters



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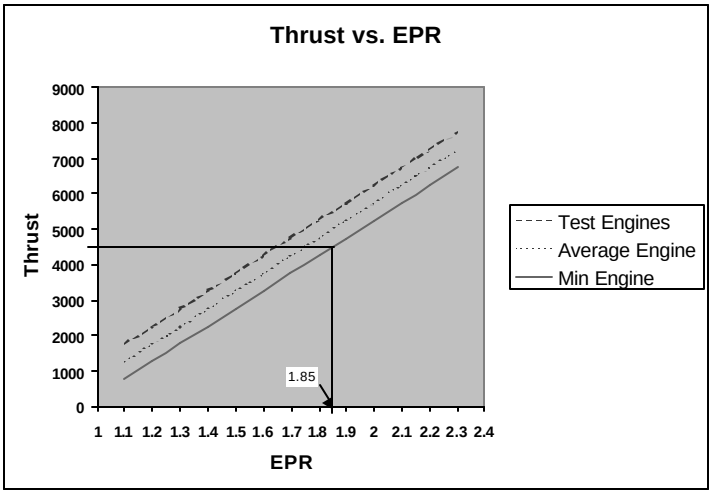

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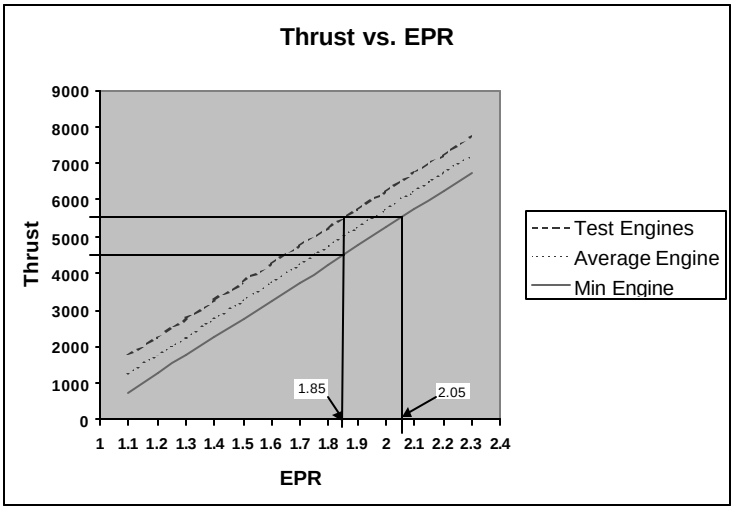

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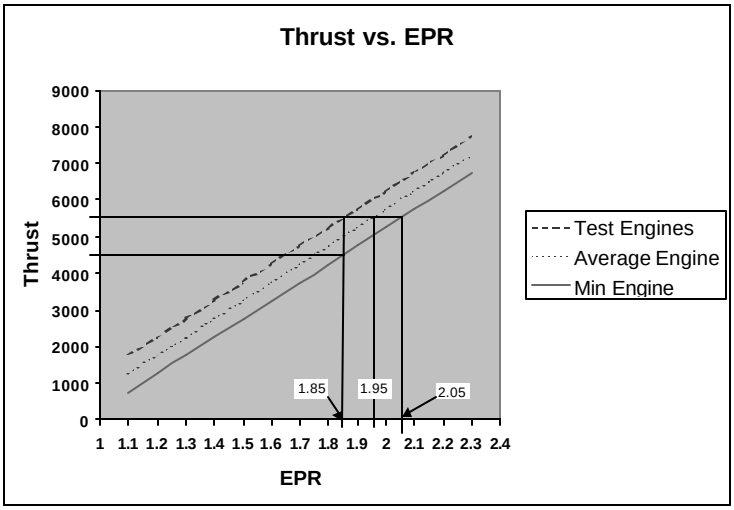

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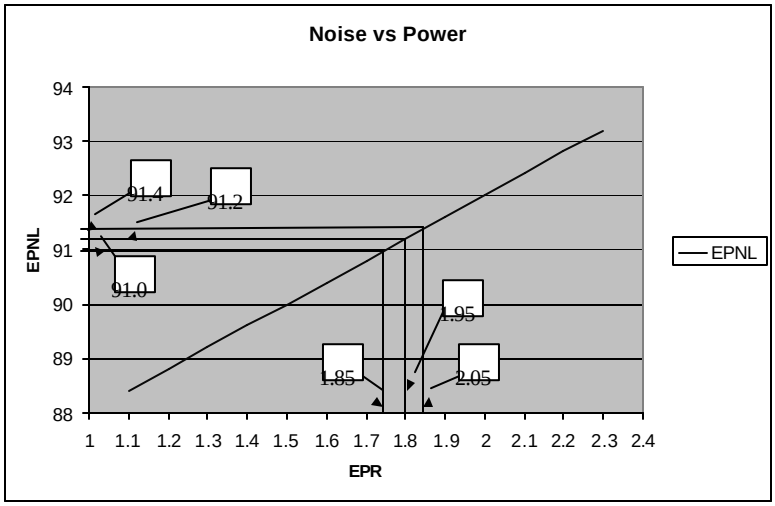

Correlating Parameters

- Benefits of Correlating Noise NPD's on F_n/d or $N_1/\sqrt{\theta}$
  - Enter NPD directly from reference performance calculations
  - Continued use of original thrust-EPR relationship not necessary
  - Less chance of error in converting from calculated thrust required to appropriate EPR on NPD

(Requires calibrated engines for all noise testing)

Acoustic Change

- **Acoustic Change per § 21.93(b)**
  - Voluntary change in type design
  - Greater than 0.1 dB increase
  - Changes are cumulative (i.e. multiple changes are not considered individually but in total)
  - FAA Letter Report FAA-AEE-95-03 provides some guidance for small airplanes
  - 14 CFR § 183.29(i) prohibits DER's from making findings of no acoustic change and equivalencies

Acoustic Change

- Potential acoustic changes due to modifications in aircraft configuration and performance such as:
  - Engines
    - Power
    - RPM
    - Exhaust systems
  - Acoustic treatment
  - Gross weight (both increase and **decrease**)
  - Other aspects of aircraft configuration such as drag

Acoustic Change

- Methods to determine modifications effect
  - Back to back performance verification by
    - Analysis
    - Flight Test
  - Testing
    - Impedance tube testing
    - Engine stand testing
    - Flyover measurements

Acoustic Change

- External Attachments Exclusion for Helicopters § 21.93(b)(4)(ii)
  - Exempts from noise regulations attachments for floats, litter kits, cameras, lights, banners, etc.
  - Issued November 5, 1996

Foreign Authorities

- Regulatory Basis
  - ICAO Annex 16 Volume I
- Guidance
  - Technical Manual (WGAR 6)
- Witnessing tests
  - Authority to Authority agreement
- Test Plan approvals
  - Agreed to by certificating and validating authority
  - Equivalent procedures must be approved by FAA

Foreign Authorities

- European Concerns
  - European Commission Ban on hushkits
    - Effective May 1, 2000
    - Ban prohibits the addition of any more older technology aircraft engines modified to meet the current noise limits
- Bilaterals do not extend to environmental findings (i.e., Part 34 and Part 36)

Why So Detailed/Restrictive?

- Protect the quality of life for the general public
- Protection of the environment
- Most important….

So I can have a quiet day at the beach!